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⑽ **Method for multi-beam manipulation of microparticles.**

⑽ Irradiating a plurality of laser beams onto different microparticles or different groups of microparticles permits trapping and/or manipulating of these microparticles or groups of microparticles. By introducing an exciting laser beam it is possible to induce chemical reactions for processing or assembling.

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[FIELD OF THE INVENTION]

The present invention relates to a method for multi-beam manipulation of microparticles. More particularly, the present invention relates to a method for multi-beam manipulation of microparticles which is useful in such various fields as bioengineering and chemistry, and permits free non-contact manipulation of multiple kinds of microparticles of the micrometer order.

[PRIOR ART]

There has conventionally been known the laser trapping method comprising trapping microparticles of the micrometer order with a laser beam, and expectation is entertained to apply this technology for cell manipulation in the field of bioengineering and for quality improvement and reactions of microparticles in the field of chemistry.

Regarding this laser trapping, the present inventors have proposed a few other methods representing the progress of micromanipulation technology, which are epoch-making methods useful in the formation of a dynamic pattern with a group of microparticles, microprocessing of microparticles, and manipulation of metal microparticles (Japanese Patent Application No.1-318,258, Japanese Patent Application No.2-78,421, Japanese patent Application No.2-402,063, and Japanese Patent Application No.3-104,517).

With these methods, it is now possible to manipulate trapping, transfer and processing of a microparticle or a group of microparticles in non-contact manner and at will.

In spite of this progress of micromanipulation technology based on laser beam, however, a method has not as yet been established, which permitted individual manipulation of a plurality of microparticles. This has formed an obstacle for the expansion of the scope of application of laser scanning

In view of the circumstances described above, the present invention has an object to provide a new method which solves the problems in the conventional methods as described above and permits trapping, processing and assembling of even a plurality of microparticles or groups of microparticles.

[SUMMARY OF THE INVENTION]

The present invention provides, as a means to solve the above-mentioned problems, a method for multi-beam manipulation of microparticles, which comprises the steps of irradiating a plurality of laser beam onto different microparticles or different groups of microparticles and trapping and/or manipulating said microparticles or said groups of microparticles.

Embodiments of the present invention include splitting a single laser beam and irradiating same after

coaxialization, and polarizing a laser beam, splitting same with a polarized beam splitter, and irradiating the resultant plurality of beams after coaxialization.

[BRIEF DESCRIPTION OF THE DRAWINGS]

Fig. 1 is a block diagram illustrating a typical system configuration applicable in the present invention;

Fig. 2 is a plan view illustrating a typical manipulation of microparticles according to the present invention;

Fig. 3 is a plan view illustrating another typical manipulation of microparticles according to the present invention; and

Fig. 4 is a plan view illustrating further another typical manipulation of microparticles according to the present invention.

[DETAILED DESCRIPTION OF THE INVENTION]

The present invention provides a method for multi-beam manipulation of microparticles. The method comprises the steps of irradiating a plurality of laser beam onto different microparticles or different groups of microparticles and trapping and/or manipulating said microparticles or said groups of microparticles.

The method for multibeam manipulation of microparticles of the present invention will now describe further in detail with reference to some examples.

Configuration of a system applicable in the method of the present invention is shown in Fig. 1. In this embodiment, a laser beam for trapping CWND: YAG (Spectron SL902T; wavelength; 1,064 nm; linear polarization) is employed. This laser beam is converted into a circular polarized beam with a $\lambda/4$ plate, and the resultant polarized beam is split into two beams by means of a polarized beam splitter. The two split laser beams are individually deflected in two axial directions with two galvanomirrors (GSZ Q325DT), then coaxialized with the polarized beam splitter. As the two beams, of which the polarization directions are at right angles to each other, are characterized by the absence of mutual interference (the intensity distribution does not vary with the relative positions of the beams). These laser beams are directed to a microscope (Nikon Uptiphot XF) via a lens system, and condensed onto a sample through an oil-impregnated objective lens ($\times 100$, NA = 1.30). The condensing spot has a size of 1 μm . The galvanomirrors are located at the opening and at the image forming positions of the microscope, respectively. Under the effect of deflection caused by the galvanomirrors, the focal position scans the sample two-dimensionally. The galvanomirrors are controlled by a computer (NEC PC9801 RA); it is possible to move the two beams at will by the operation of keyboard. Laser scanning makes it possible to align a plurality of microparticles with each

beam, and even to trap metal microparticles or low-refraction microparticles. Any cause of laser scanning can freely be set through keyboard input. For an excited laser beam, on the other hand, a Q-switch YAG laser (wavelength: 355 nm; pulse width: approx. 30 ps) is used, and is condensed on the sample in coaxialization with the trapping laser beam. The progress of microparticle manipulation is observed through a CCD camera and a video recorder. The position of the laser beam and the current status of manipulation are displayed in a superimposed manner of the monitor screen.

Now let use see an example in which, by the use of the above-mentioned system configuration, micromanipulation was carried out with a sample prepared by dispersing monodispersive polystyrene microparticles having a diameter of 3 μm in ethylene glycol containing acrylic acid (monomer), N,N'-methylenebisacryl amid (linking agent) and DALOCURE 1116 (photo-polymerization initiator) dissolved therein.

Example of manipulation

First, as shown in Fig. 2, polystyrene latex microparticles of the above-mentioned sample are trapped with two individual beams, and are caused to come into contact with each other by moving the beams. Then, an excited laser is irradiated onto the contact point to cause photo-polymerization to start. A few seconds after laser irradiation, acrylic acid gel is generated on the surfaces of the polystyrene microparticles, thus causing welding of two microparticles. After confirming welding by moving the beams, laser scanning of one of the beams is started to trap connected microparticles. Then, as shown in Fig. 3, the other beam traps the other microparticle while moving, and is caused to move to an arbitrary position of the two connected microparticles for contact thereof. The excited laser is irradiated onto the contact point in the same manner as above to repeat welding through photo-polymerization. Repetition of this cycle of manipulation permits building a structure based on microparticles.

Then, for the purpose of causing a rotary motion of this microparticle structure, as shown in Fig. 4, (a) first, laser scanning is discontinued to trap two arbitrary points on the structure; (b) one of the beams is fixed so as to serve as the rotation axis; and (c) the other beam is caused to start circular scanning around the fixed rotation axis as the center of rotation. Then, the microstructure begins rotary motion.

It is needless to mention that any of various laser beam optical systems may be adopted in the manipulation as described above, and any of various organic, inorganic and metal microparticles may be covered in addition to organic polymers. A biological sample such as a living cell may also be used.

This method permits manipulation of microparti-

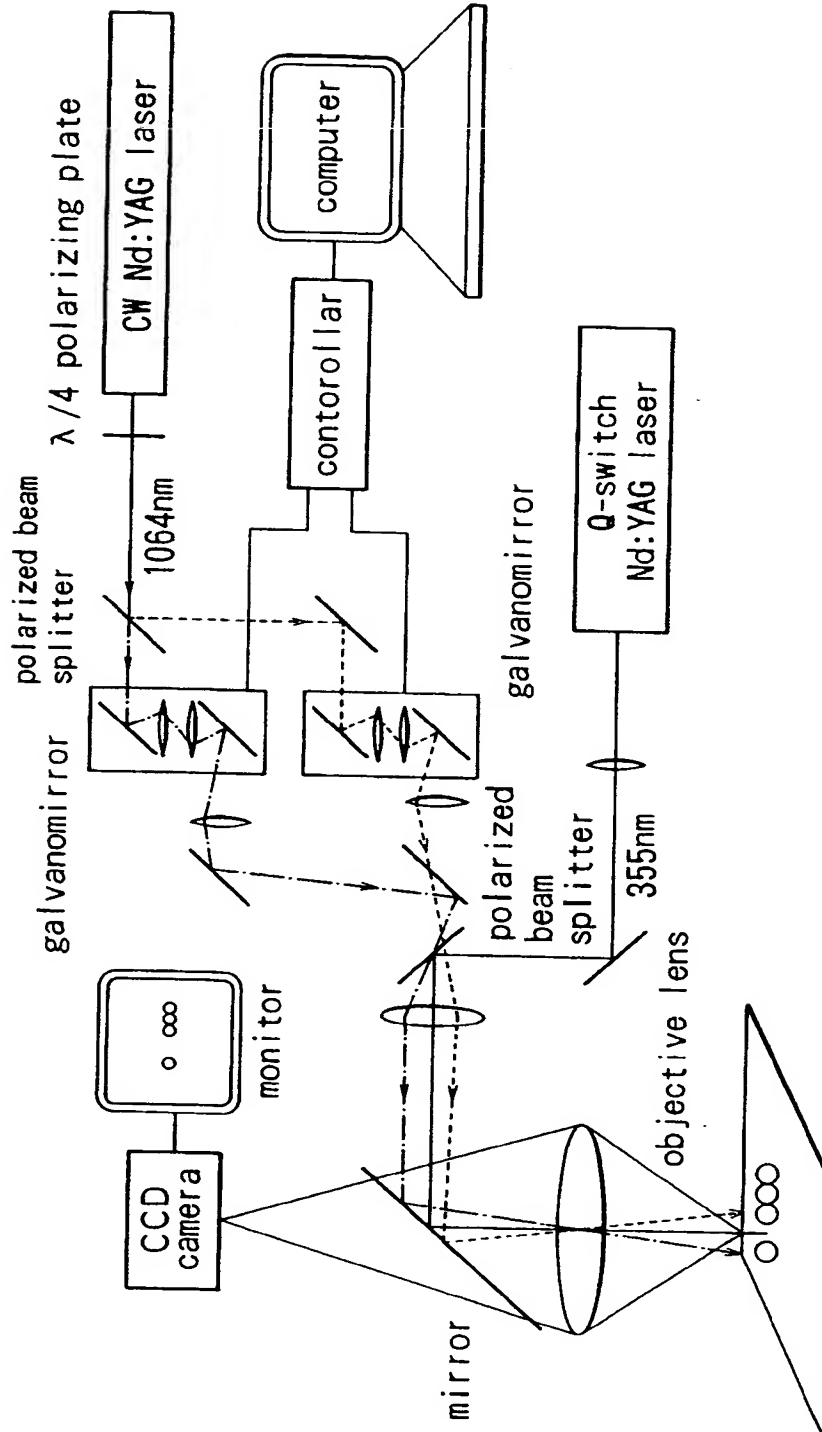
cles with two trapping laser beams not mutually interfering just as with two human hands. Manipulation is fully controllable by a computer. By coaxially introducing an excited laser beam, furthermore, it is possible to induce chemical reactions for processing or assembling.

According to the method for micromanipulation of the present invention using a plurality of laser beams, it is possible to conduct processing, assembling or a mechanical motion of a plurality of microparticles or a plurality of groups of microparticles. This method is not only directly applicable in the form of an assembling or driving apparatus of a micro-machine, but also permits construction and control of a microstructure of the micrometer order important physics, chemistry, mechanical engineering and electrical engineering.

Claims

1. A method for multi-beam manipulation of microparticles which comprises the steps of irradiating a plurality of laser beams onto different microparticles or different groups of microparticles, and trapping and/or manipulating said microparticles or said groups of microparticles.
2. A method as claimed in claim 1 wherein a single laser beam is divided and coaxialized for irradiation.
3. A method as claimed in claim 2 wherein said laser beam is polarized and split by means of a polarized beam splitter, and a plurality of coaxialized beams are irradiated onto the microparticles or groups of microparticles.
4. A method as claimed in claim 2 or claim 3 wherein an exciting laser beam is coaxially introduced to induce chemical reaction.

FIG. 1



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FIG. 2

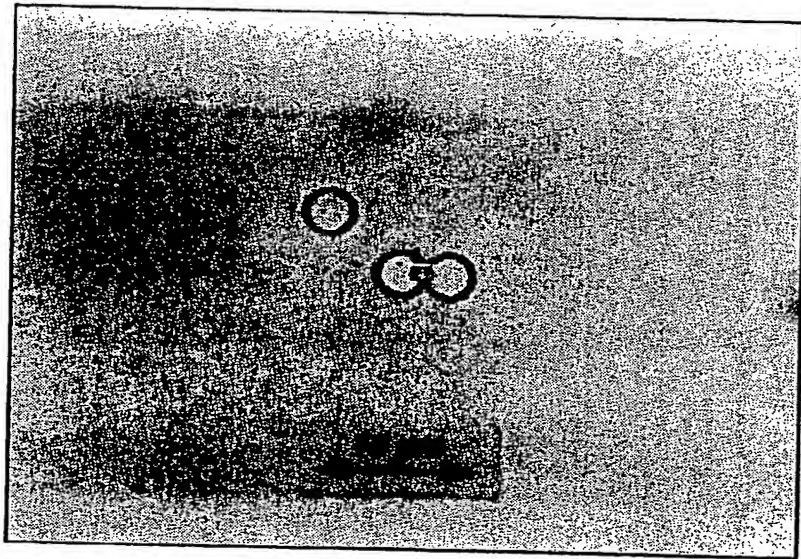


FIG. 3

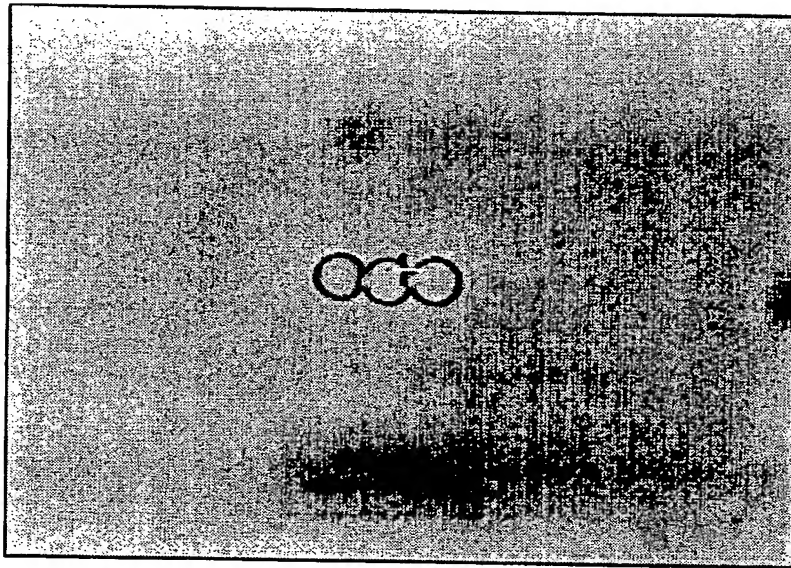
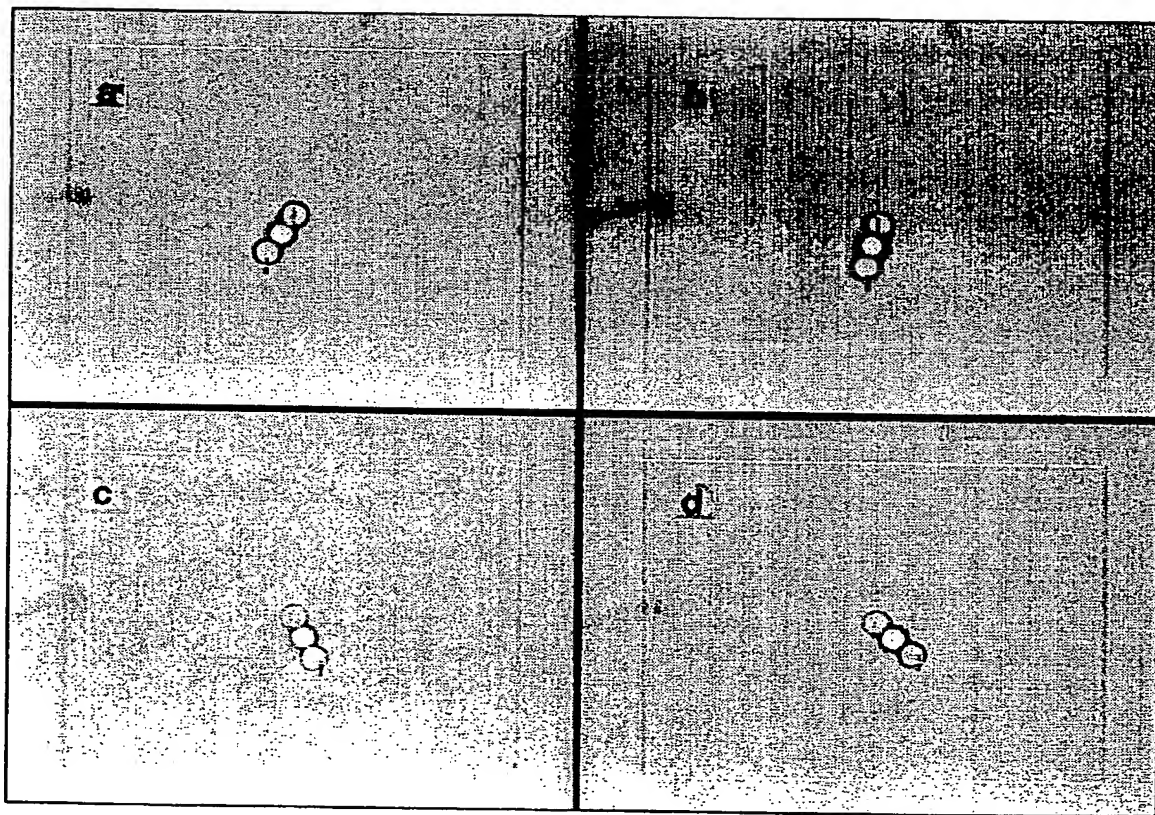


FIG. 4



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European Patent
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EUROPEAN SEARCH REPORT

Application Number

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	SCIENCE vol. 249, 17 August 1990, LANCASTER, PA US pages 749 - 754 M.M.BURNS ET AL. 'Optical matter:Crystallization and Binding in intense optical fields' * page 750, column 1, line 11 - line 41; figure 1 *	1-4	H05H3/04
A	--- JAPANESE JOURNAL OF APPLIED PHYSICS, SUPPLEMENTS vol. 30, no. 5B, May 1991, TOKYO JA pages L.907 - L.909 , XP000237703 K.SASAKI ET AL. 'Laser-scanning micromanipulation and spatial patterning of fine particles' * figure 1 *	1	
P,X	--- APPLIED PHYSICS LETTERS. vol. 60, no. 3, 20 January 1992, NEW YORK US pages 310 - 312 , XP000297655 H.MISAWA ET AL. 'Multibeam laser manipulation and fixation of microparticles' * figure 1 *	1-4	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			H05H
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 26 FEBRUARY 1993	Examiner GALANTI M.
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons</p> <p>Δ : member of the same patent family, corresponding document</p>			

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